Reprocessing activities at swisstopo (LPT)

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Motivation for Reprocessing

- Achieve homogenous time series

- Switch to absolute antenna models (before reprocessing not possible in order to avoid jumps for the velocity estimation)

- Adopt new processing options from Bernese Version 5.2

- **Compute different solutions to gain experience with new solution types**

- Enhance the network with valuable sites showing a good performance (seen in retrospect)

- Participate in the reprocessing project of the EPN-Repro2 / GNSS4SWEC
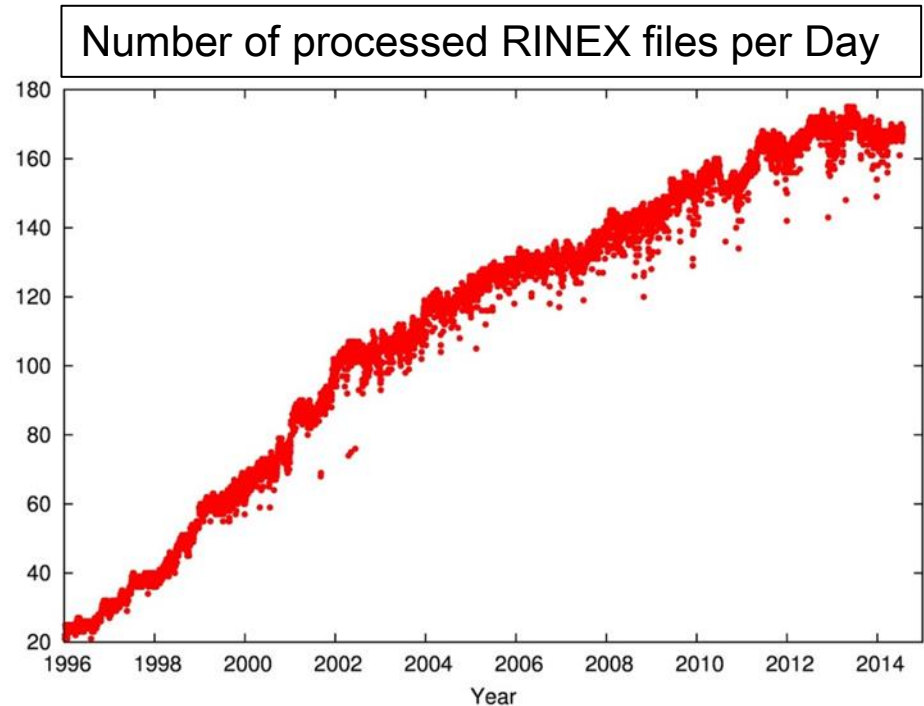
Processed Network
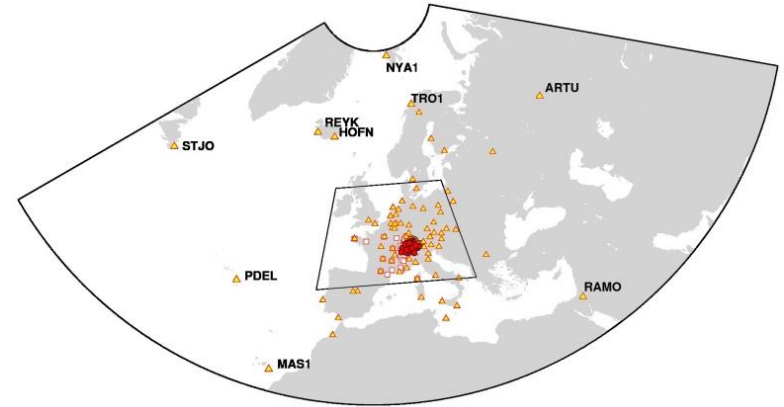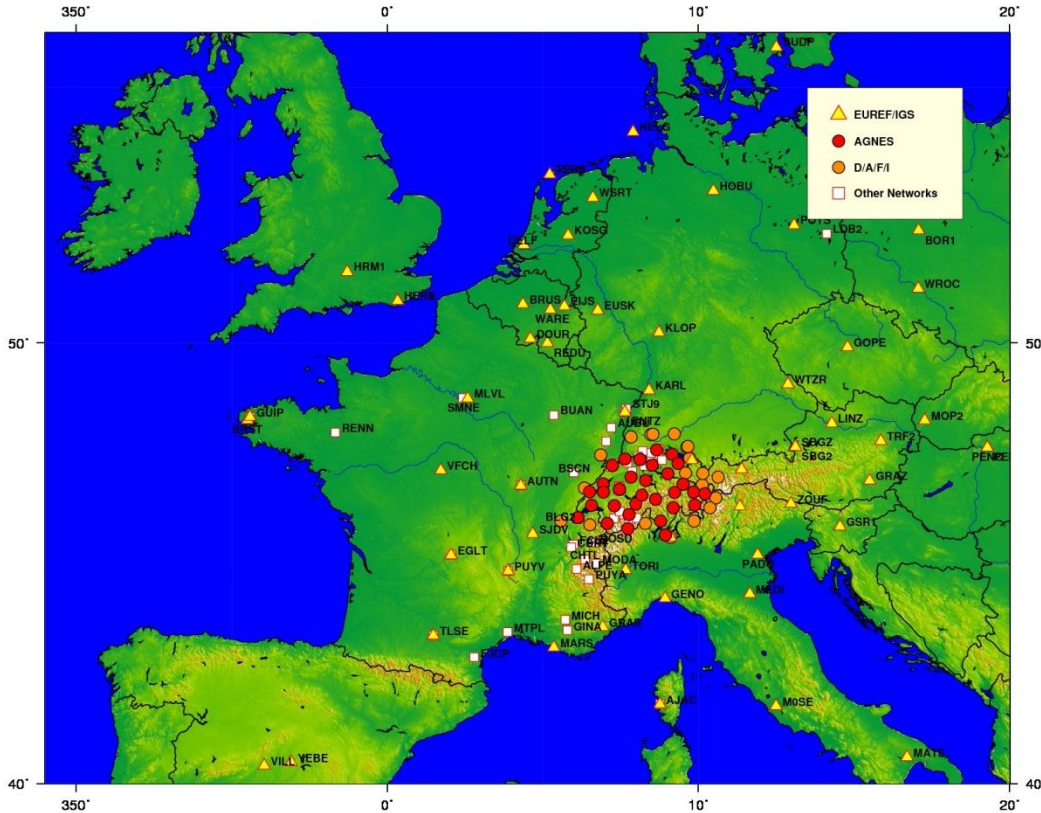
- About 190 sites
- From different types of networks:
  - IGS/EUREF
  - AGNES
  - D/A/F/I
  - Others

General Remarks on the Reprocessing

- Time span 1996, DOY 007 till 2014, DOY 207

- Number of sites increased from 20 sites (1996) to 170 sites (2014)

- CODE orbits/ERPs from 2011/2013 reprocessing used

- Alignment to IGb08 reference frame

Number of processed RINEX files per Day

Processing Options: First Reprocessing (Repro2_1)

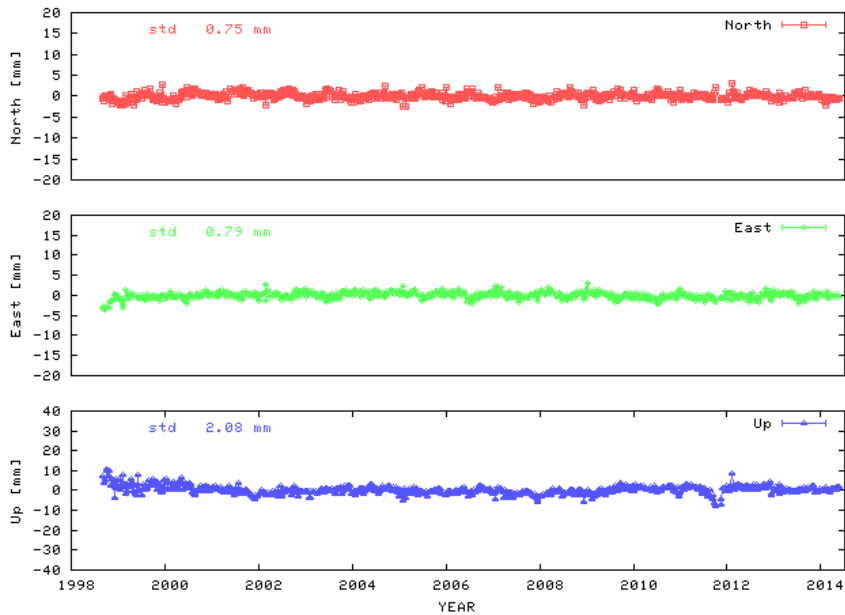Make use of Bernese Software (BSW52) options, amongst others:

- Troposphere GMF / Chen Herring for gradients

- Absolute antenna calibration group values, specific for GLONASS also ("I08")

- Following IERS2010 conventions
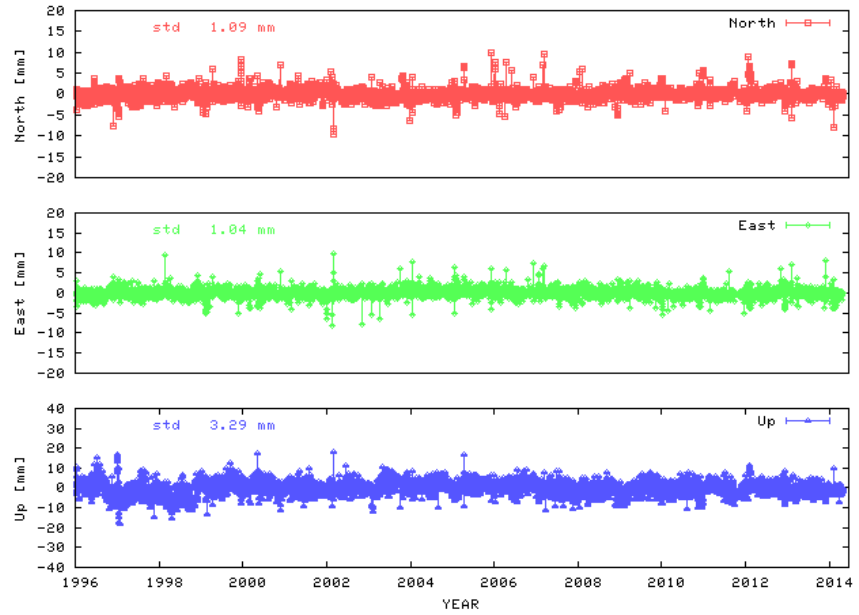
- Higher order ionosphere

Multi-Year Solutions Repeatabilities Old vs. Repro2_1

Weekly repeatability ZIMM old [mm]

Daily repeatability ZIMM Repro2_1 [mm]

RMS of all sites	North	East	Up
Multi-Year (old)	1.4 mm	1.2 mm	3.5 mm
Multi-Year (Repro2_1)	1.6 mm	1.4 mm	4.5 mm

Repro2_1 solution shows a nice performance (RMS difference smaller than the expected factor of 2.6 ($\sqrt{7}$), weekly vs. daily)
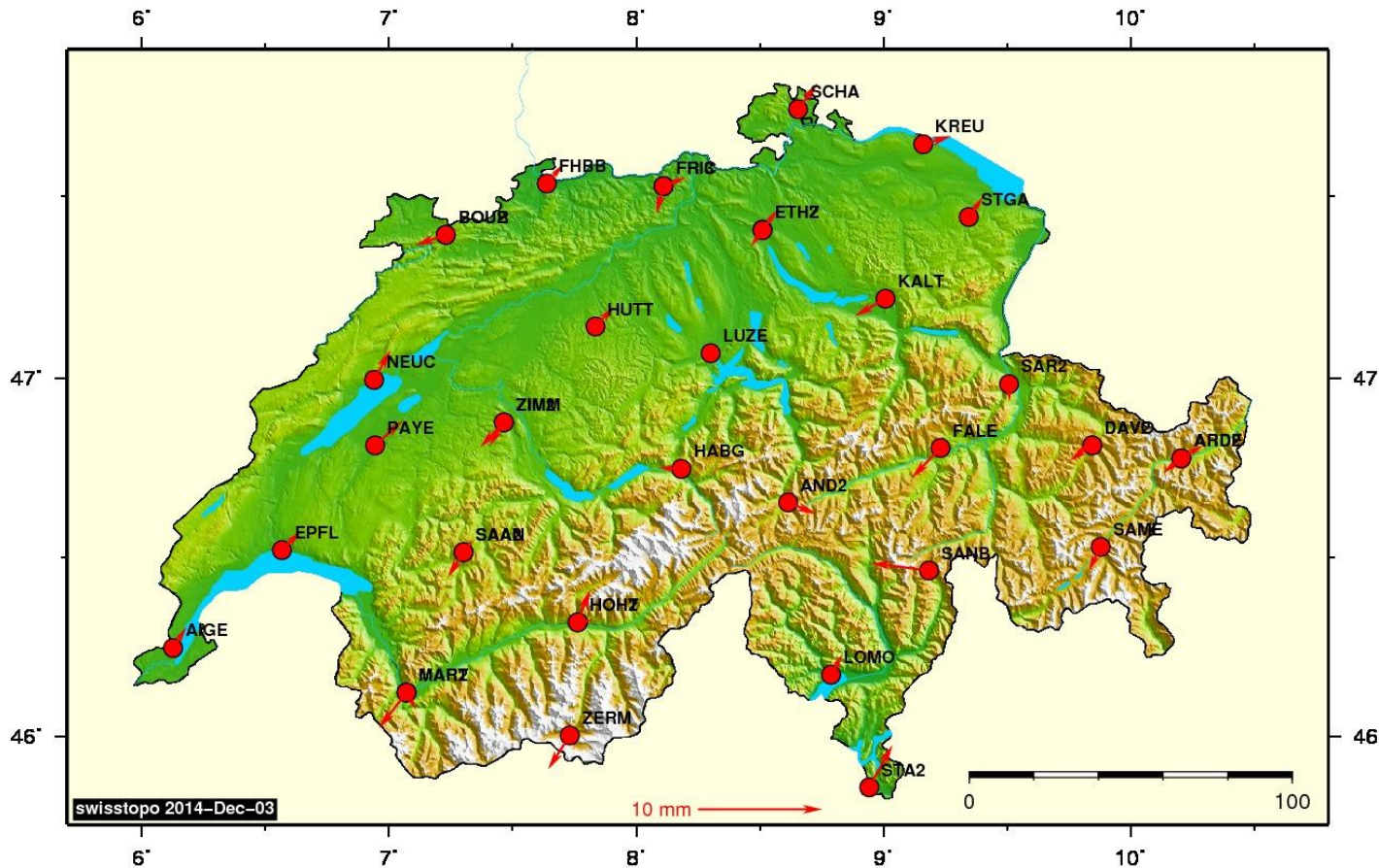
Helmert Coordinate Differences: Old vs. Repro2_1 Multi-Year Solution
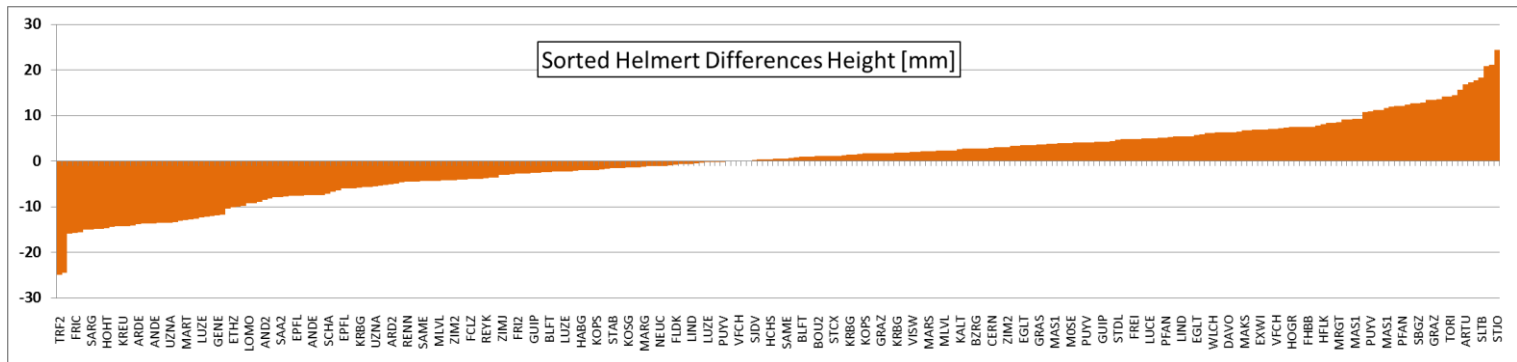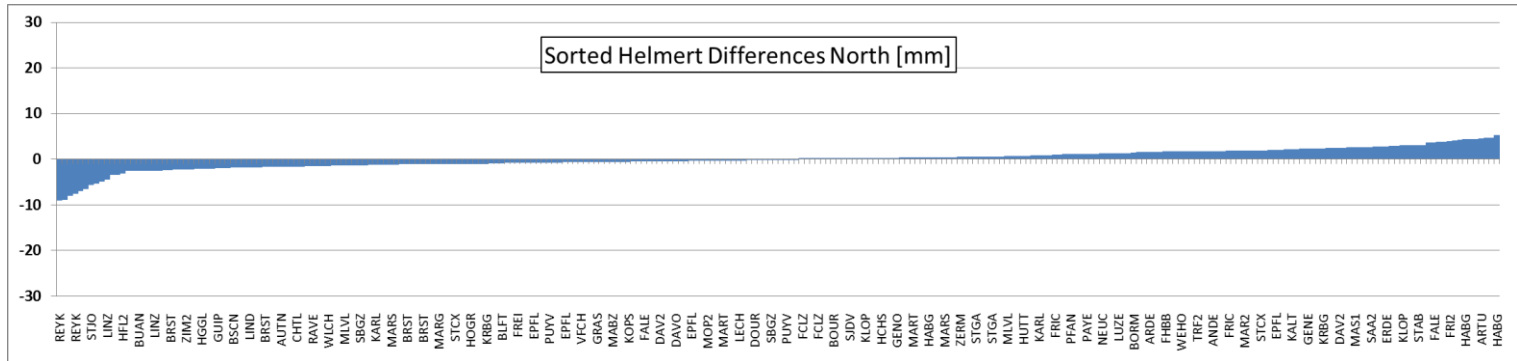
- RMS of all sites: 2.1 mm North / 1.9 mm East / 8.0 mm Up
- Mainly due to different processing options (especially due to antenna model change from IGS01(relative) to IGS08 (absolute))

Horizontal coordinate differences (Switzerland)

RMS:
N/E 1.7 mm

Maximum:
5 mm
(San Bernardino)

Vertical coordinate differences (Switzerland)
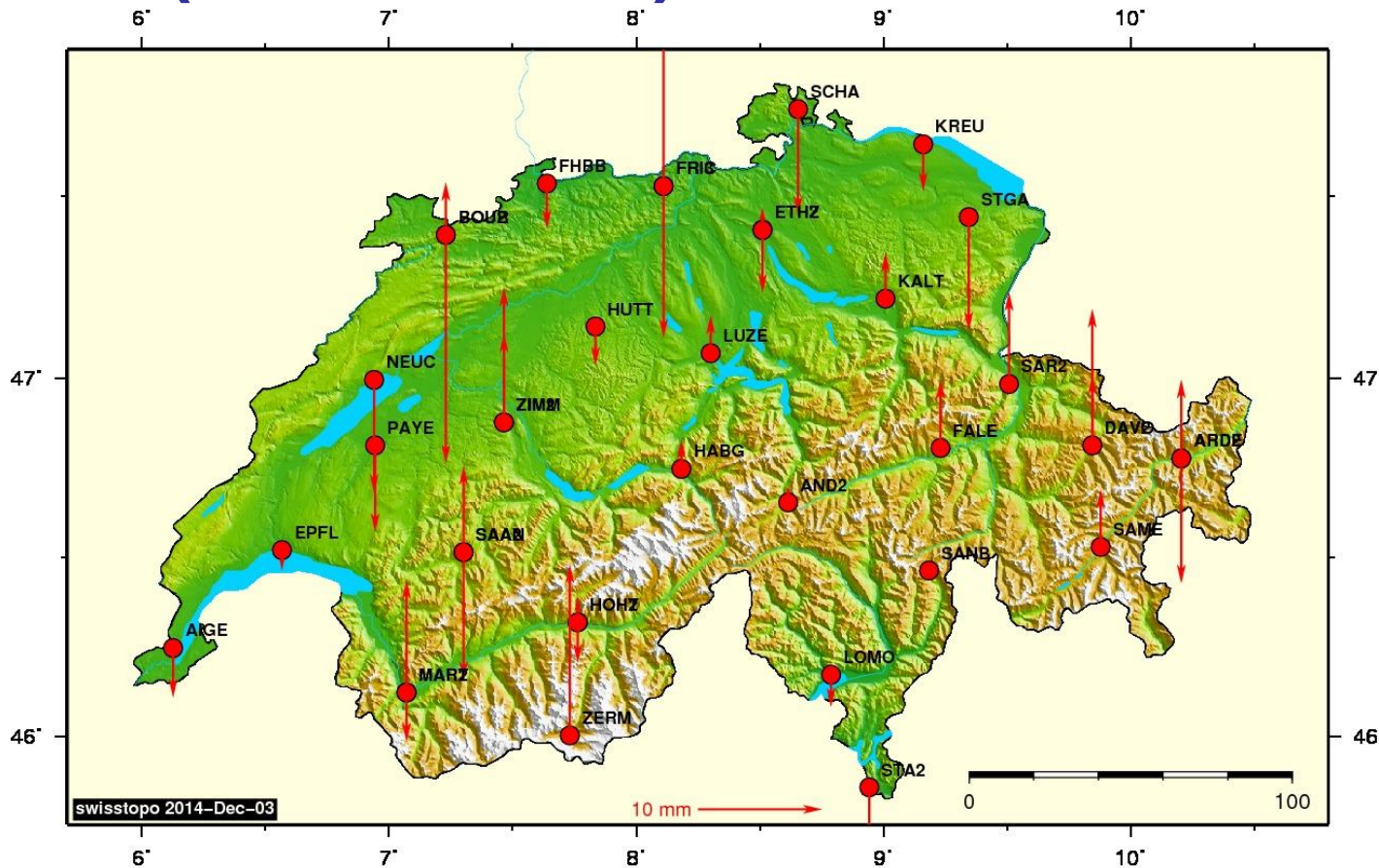
RMS:
Height 8 mm

Maximum:
Up to 18 mm
(Bourrignon)

Normally:
< 10 mm

→ Main reasons: Switch to absolute antenna models, troposphere modelling

Horizontal Velocity Field (Central Europe)
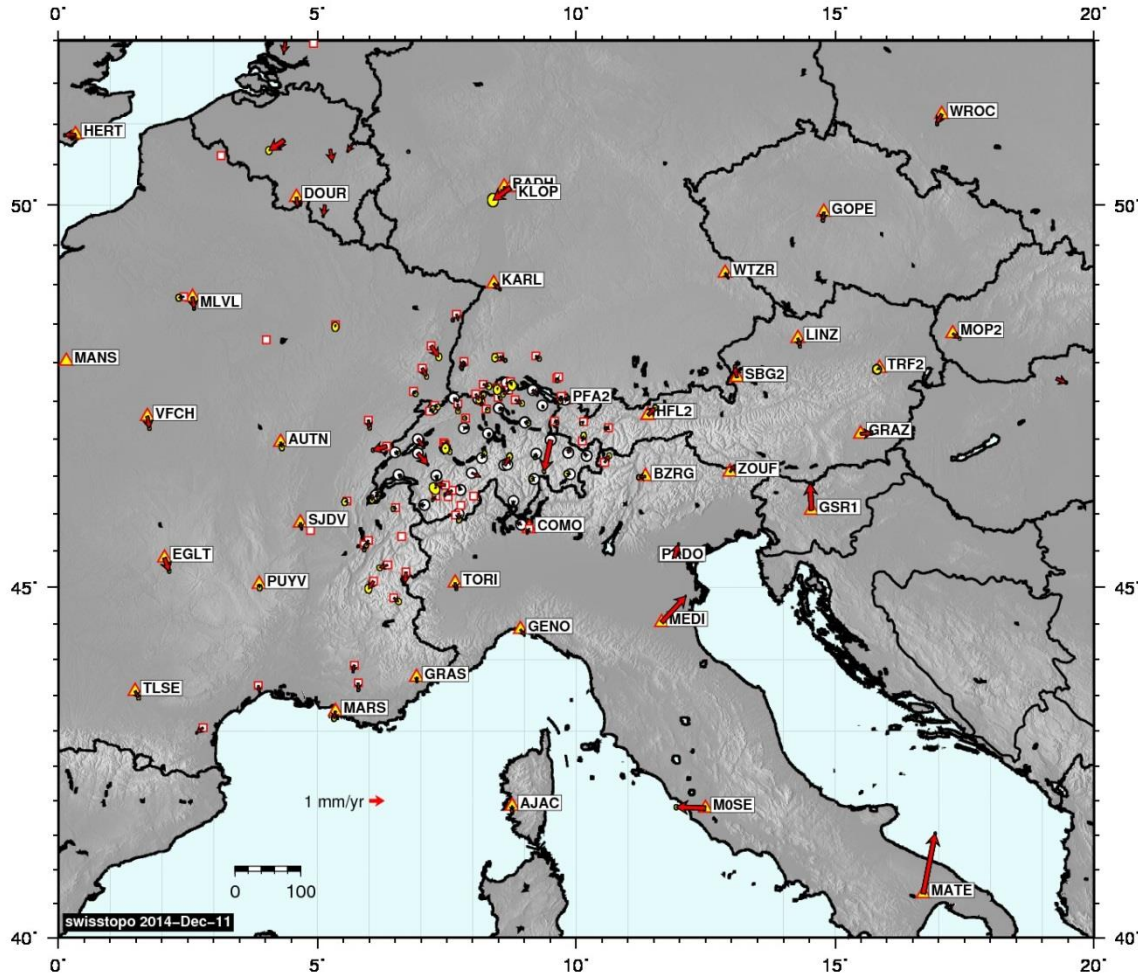
Relative to ETRF2000 and Zimmerwald

Vertical Velocity Field (Central Europe)
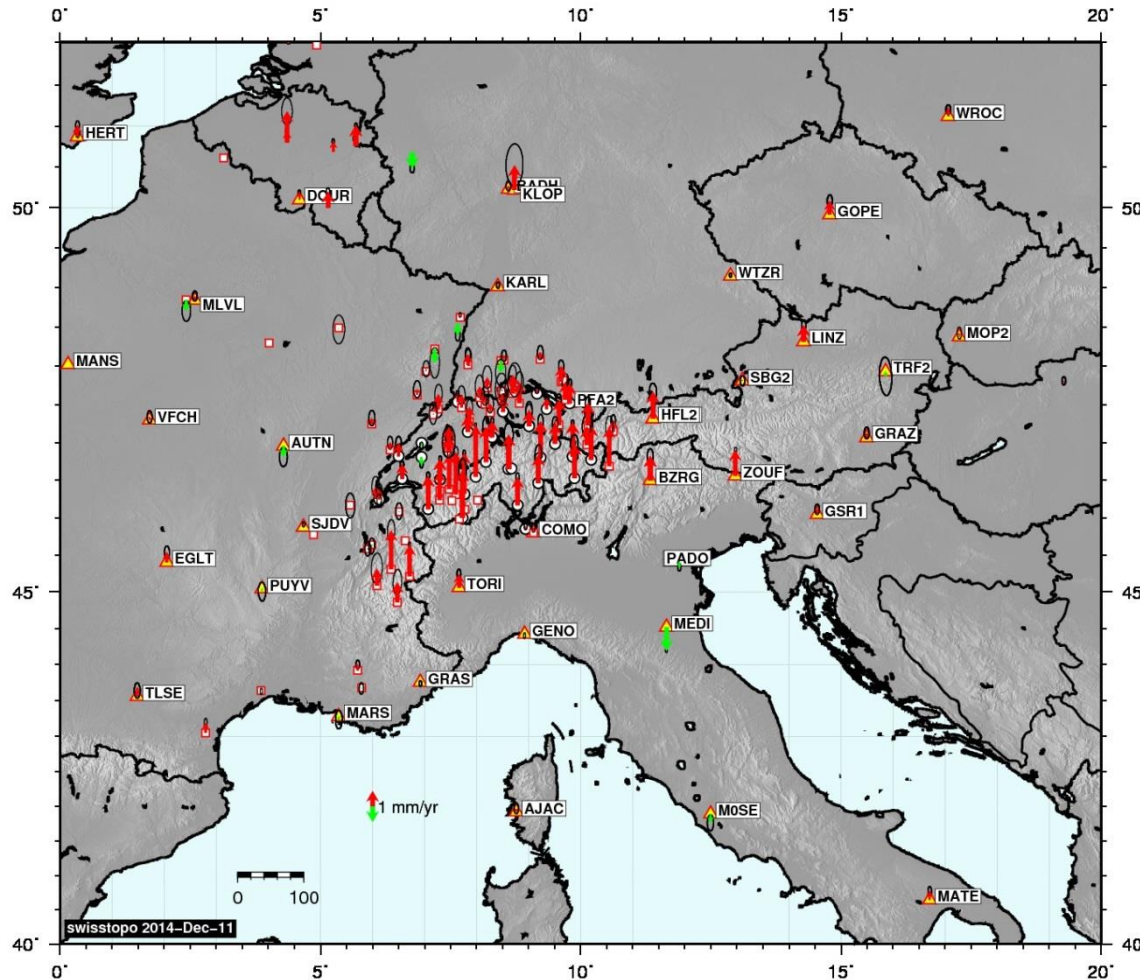
Vertical velocities in the IGb08 reference frame

Vertical Velocity Field (Switzerland)
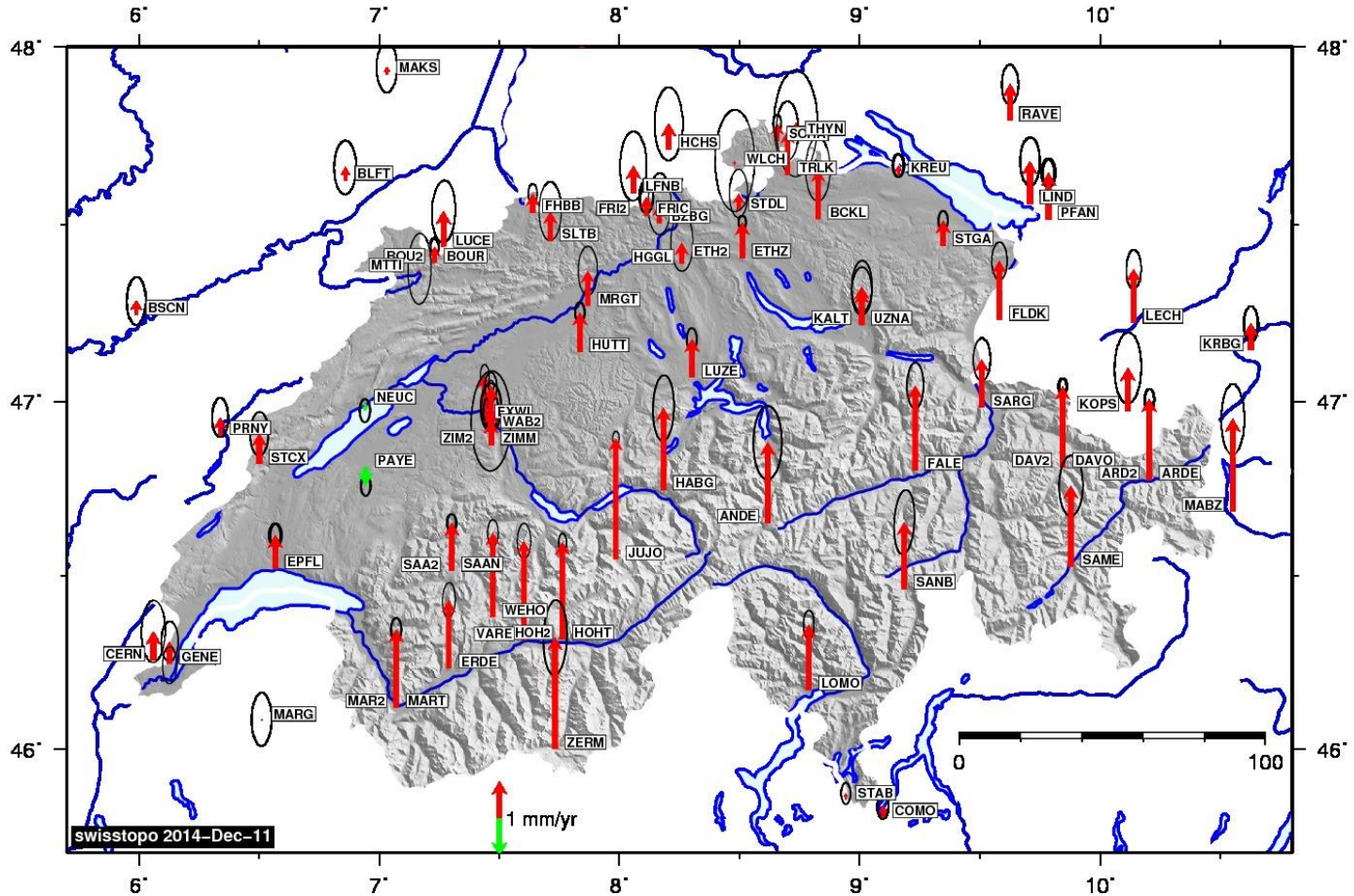
Vertical Velocity Differences (Switzerland)
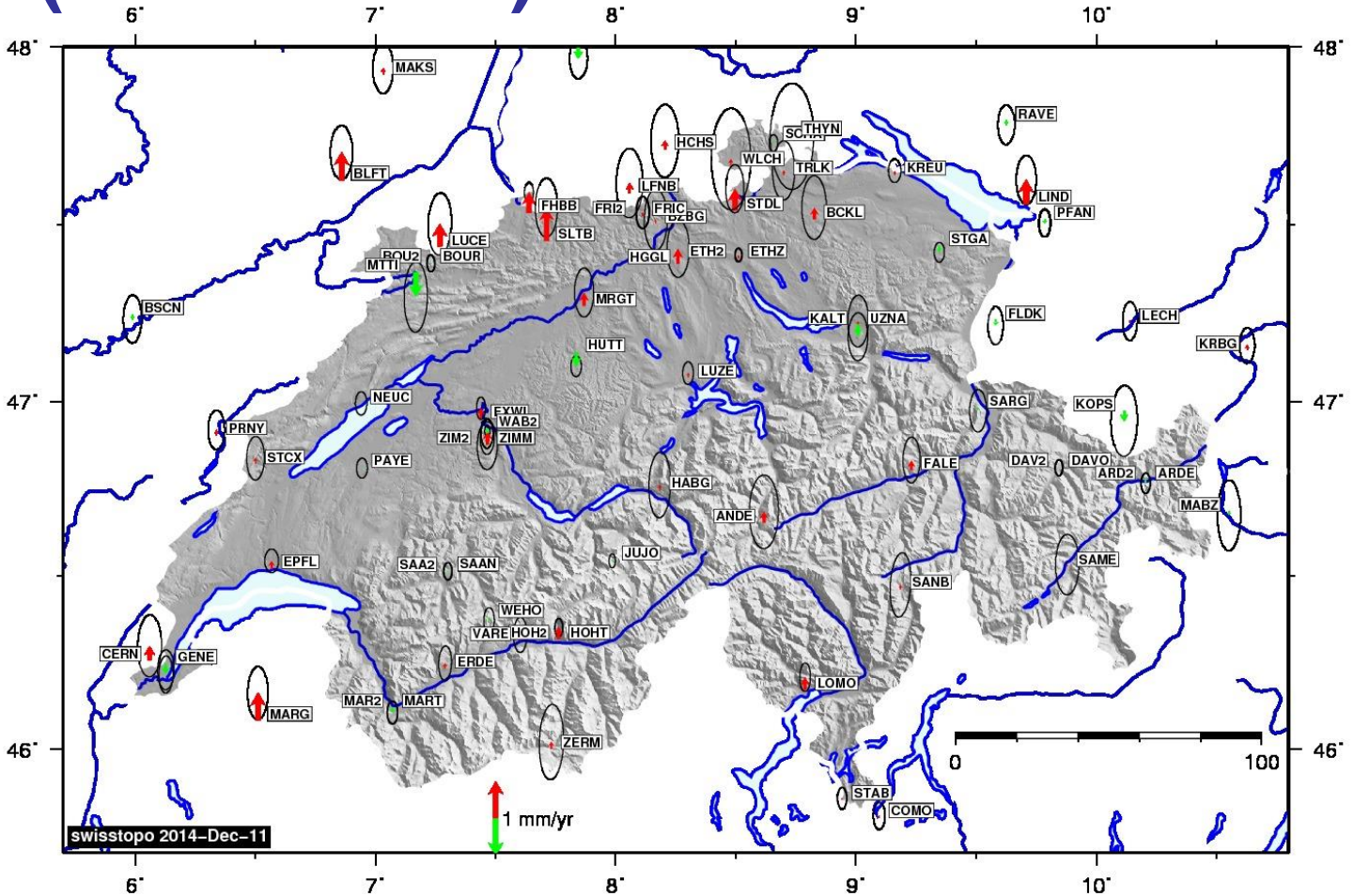
With respect to the mean of all AGNES sites

Further solution types for Repro2

I08_GMF:
Repro2_1 solution (absolute antenna models, Global mapping function)

C08_VMF:
Individual antenna calibration, Vienna mapping function

C08_VMF_APL:
+ Non-tidal atmospheric pressure loading (TU Vienna)

C08_VMF_APL_ISB:
+ GPS-GLO intersystem biases activated (3 translations and 1 tropo)

C08_VMF_APL_GPS-only:
GPS-only solution

Coordinate Repeatabilities (Multi-Year solution)

	Repeatabilities (RMS) [mm]		
	N	**E**	**U**
I08_GMF	1.54	1.41	4.53
C08_VMF	1.54	1.40	4.30
C08_VMF_APL	1.51	1.37	4.08
C08_VMF_APL_ISB	1.51	1.36	4.11
C08_VMF_APL_GPS-only	1.51	1.36	4.12

- Best coordinate repeatabilities show the solutions with Vienna Mapping Function (VMF) and non-tidal Atmospheric Pressure Loading (APL)
- GPS+GLO solution with slightly better Up repeatabilities than GPS-only, on the same level for the horizontal components.

Influence Vienna Mapping Function and non-Tidal Atmospheric Pressure Loading

RMS Repeatability: Improvement GMF (no APL) -> VMF APL [mm]
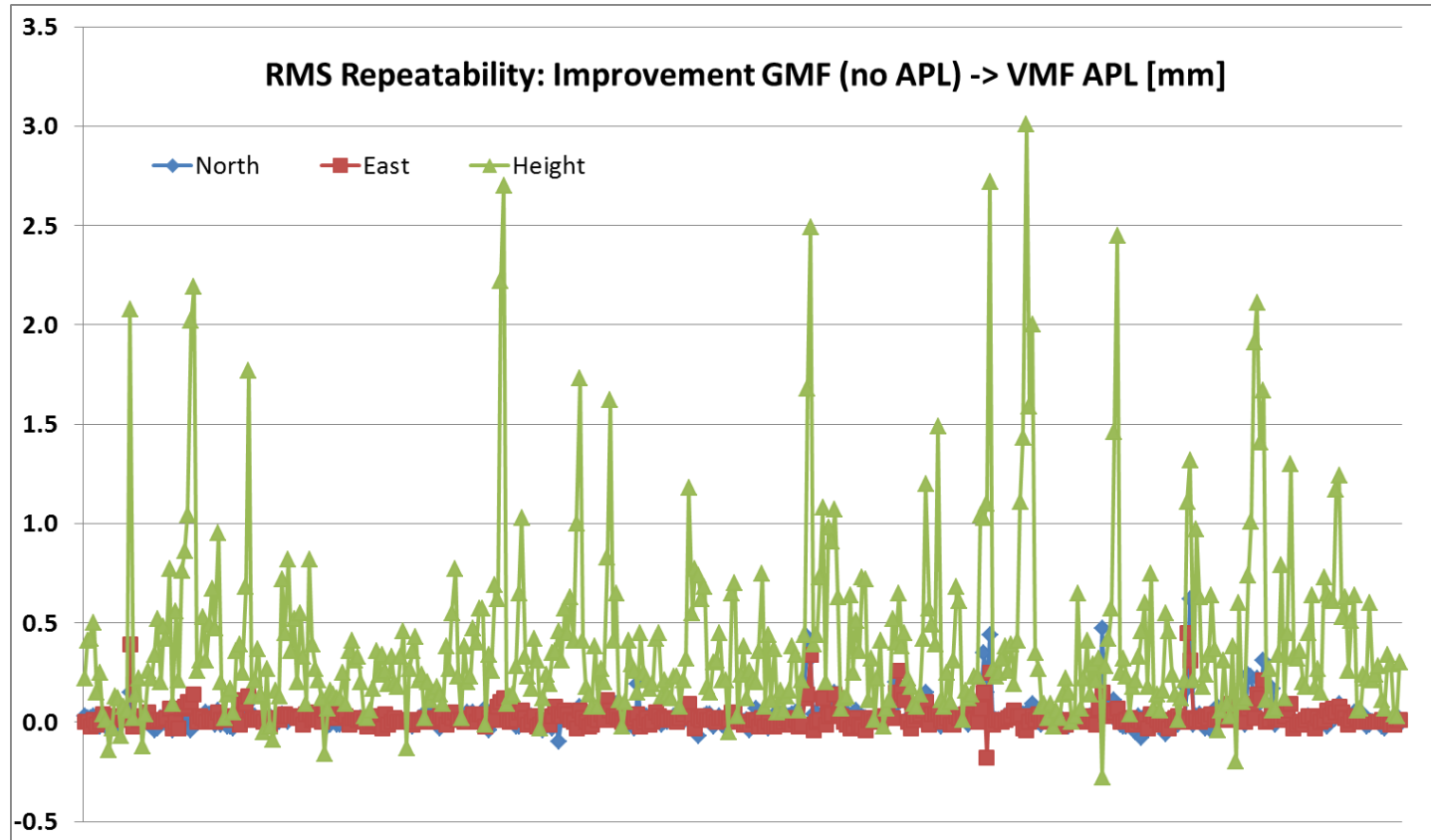
- Mean RMS improvement Height: 0.23 mm due to VMF and 0.22 mm due to non-tidal APL

Coordinate differences: Helmert-Transformations (3 Par)

	RMS [mm]			Min/Max [mm]		
	N	**E**	**U**	N	E	U
I08+GMF vs. C08+VMF+APL	0.8	0.8	1.8	-2.5 / 9.8	-8.2 / 3.6	-9.9 / 9.2
C08+VMF+APL vs. C08+VMF	0.1	0.1	0.4	-0.9 / 0.5	-1.2 / 0.3	-4.7 / 1.8
GPS-only vs. GPS+GLO	0.5	0.3	1.3	-3.1 / 3.7	-2.4 / 1.4	-9.6 / 6.6
GPS-only vs. GPS+ GLO+ISB	0.2	0.1	0.4	-1.7 / 1.0	-0.6 / 0.7	-2.8 / 1.5

- Largest influence when switching to individual antenna models (C08) and VMF
- Also between GPS-only and GPS+GLO differences visible
- With estimated Intersystem Biases, GPS+GLO is very close to GPS-only

Coordinate Differences Height: GPS+GLO vs. GPS-only

Sorted Helmert Differences Height [mm]
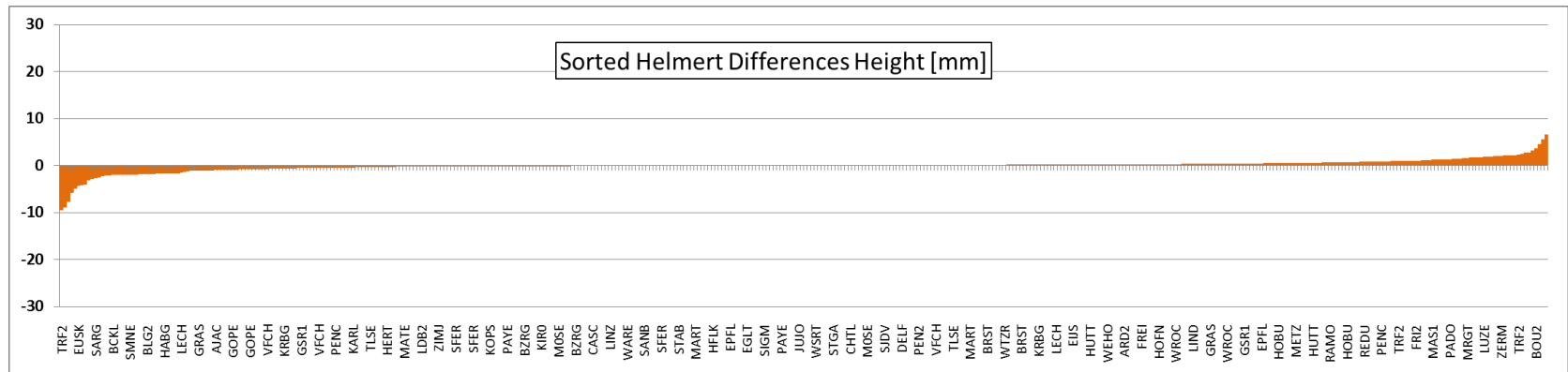
10 solutions show differences larger than 4 mm (Height), thereof 7 with individual

Antenna calibration values:

```
TRF2_E    -9.58  |  LEIAR25.R3      BEVA (Individual)
KOPS_C    -8.88  |  LEIAR25.R3      BEVA (Group)
TORI_D    -7.80  |  LEIAR25.R3      NONE (Individual)
LAMP_C    -5.80  |  LEIAR25         NONE (Group
HOFN_D    -4.94  |  LEIAR25.R4      LEIT (Individual)
EUSK_D    -4.34  |  LEIAR25.R4      LEIT (Individual)
BADH_B    -4.18  |  LEIAR10         NONE (Individual)
------------------------------------------------------
ZERM_C     4.60  |  TRM59800.00     NONE (Individual)
MARS_E     5.54  |  TRM57971.00     NONE (Group)
FRI3       6.56  |  TRM59800.00     NONE (Individual)
```

Velocity differences I08_GMF vs. C08_VMF_APL
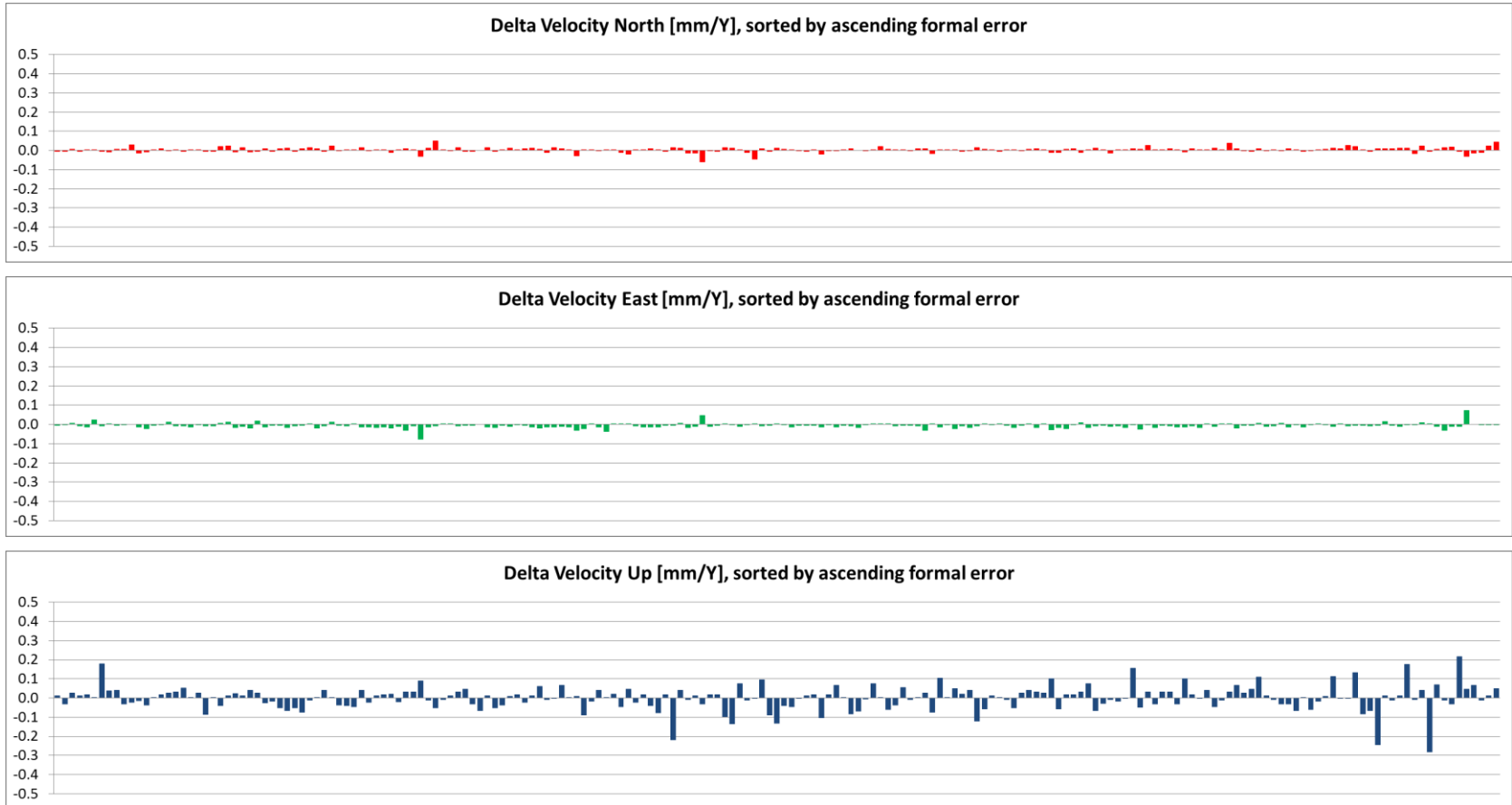
Velocity differences GPS-only vs. GPS+GLO

Delta Velocity North [mm/Y], sorted by ascending formal error

Delta Velocity East [mm/Y], sorted by ascending formal error

Delta Velocity Up [mm/Y], sorted by ascending formal error
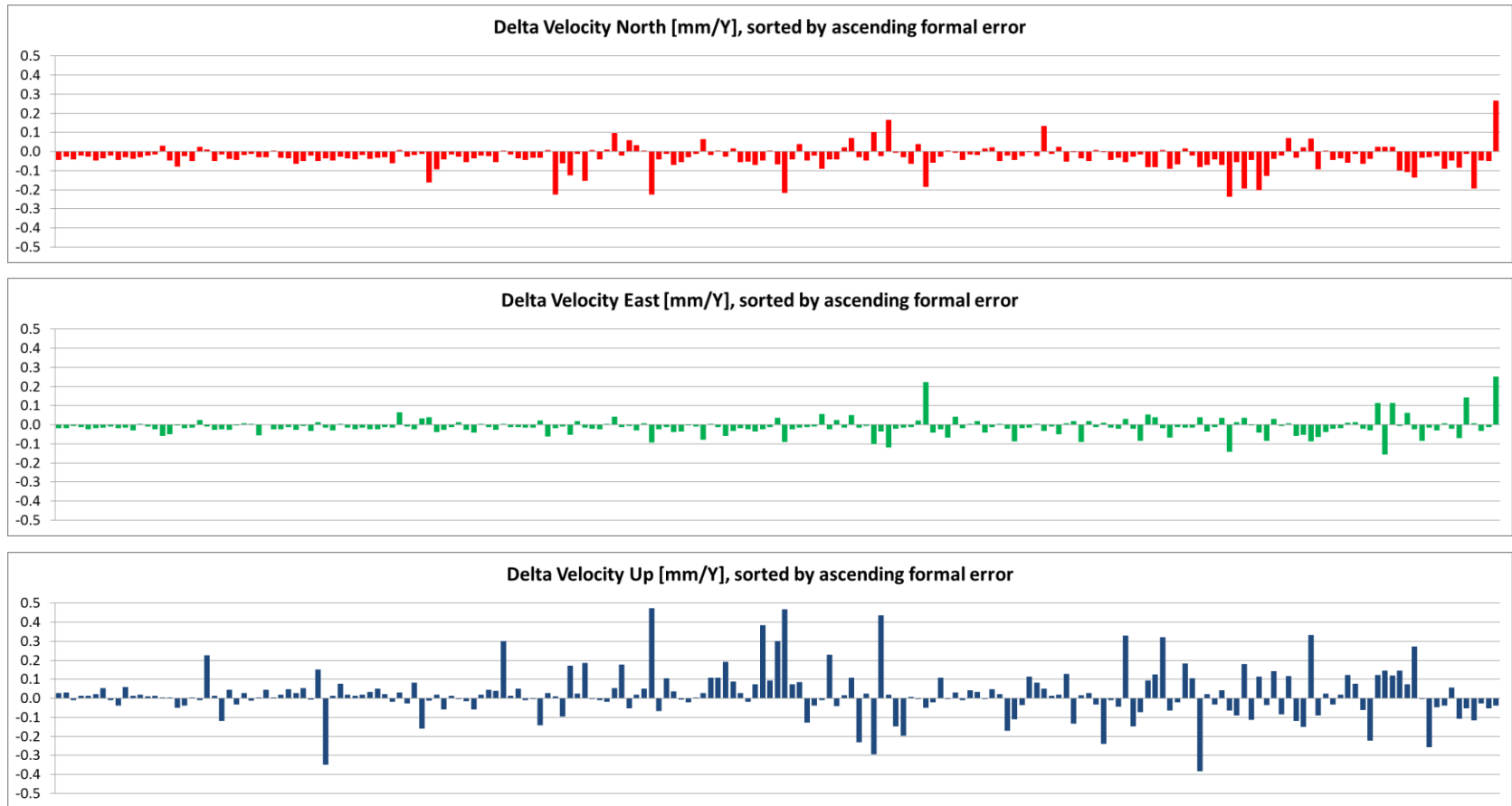
Velocity differences: Summary

	RMS [mm/Y]			Offset [mm/Y]		
	N	**E**	**U**	N	E	U
I08+GMF vs. C08+VMF+APL	0.01	0.01	0.06	-0.01	0.00	-0.06
C08+VMF+APL vs. C08+VMF	0.01	0.01	0.05	0.00	0.00	-0.02
GPS-only vs. GPS+GLO	0.04	0.06	0.12	0.01	0.03	-0.02
GPS-only vs. GPS+ GLO+ISB	0.02	0.03	0.04	0.01	-0.01	0.00

- Velocity differences are very insensitive to processing options
- Largest influence when switching from GPS-only to GPS+GLONASS (but RMS only 0.12 mm/Y for Up component)
- Estimating Inter-System Biases clearly reduces the difference between GPS+GLO and GPS-only solution

Contribution to EPN-Repro2

- Two solution types delivered:

  - "LP0": I08+GMF

  - "LP1": C08+VMF+APL(non-tidal)

- Generation of coordinate and troposphere SINEX files containing all processed EPN and IGS sites (about 100 stations)

- Coordinate SINEX files based on 1-day solutions

- Troposphere SINEX files based on the middle day of a three daily normal equation combination (improves troposphere estimates at the day boundaries)

Conclusions

- A time series from **1996 to 2014** with more than **190 sites** is available (I08, GMF)

- **Two new repro2 runs** performed (C08 VMF / GPS-only) started from single-difference files. **Further solution types** generated on normal-equation level using ADDNEQ (non-tidal APL, GPS-GLO intersystem biases)

- Best coordinate **repeatabilities** with GPS+GLO+VMF+APL

- Influence on **coordinates** mainly caused by used antenna model

- Influence of processing options on **velocities** very small, largest effects by GPS vs. GPS-GLO

- **Contribution to EPN-Repro2** with two solution types

- **Current solutions from routine processing** extend the available time span of the multi-year solution (for velocity estimation) and provide up-to-date estimates of station coordinates